Using terrestrial lidar scans to identify structural metrics of the forest canopy correlated to snow depth distribution

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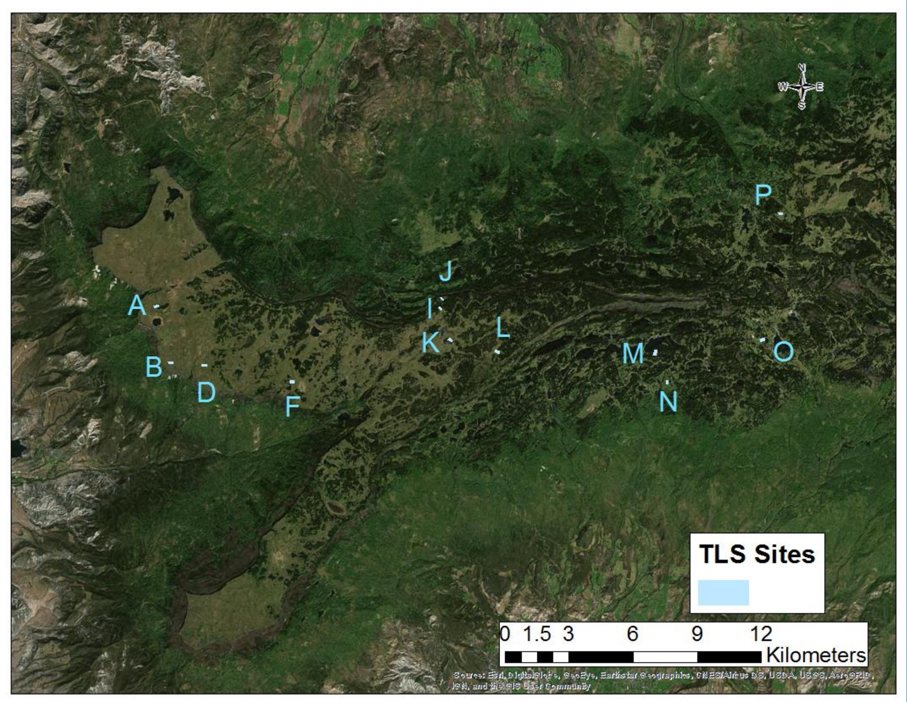
Objective: Using terrestrial laser scans (TLS) from multiple sites across Grand Mesa, CO I will describe the relationship between forest cover and snow depth distribution. I will analyze snow depth maps and canopy parameters from TLS for correlation using a range of statistical approaches.

Background: Snow distribution is controlled by many biophysical and geographical attributes of the landscape such as vegetation cover and surface roughness. In vegetated and forested environments, vegetation has been observed to strongly control snow depth distribution (Deems et al., 2006, Trujillo et al., 2007) by the mechanisms of canopy interception and wind redistribution from open areas to forest edges. The effect of forest canopy on snow depth is dependent upon the stand Density (Anderson, 2014), species and stand configuration, as well as climate (Dickerson-Lange et al., 2017).



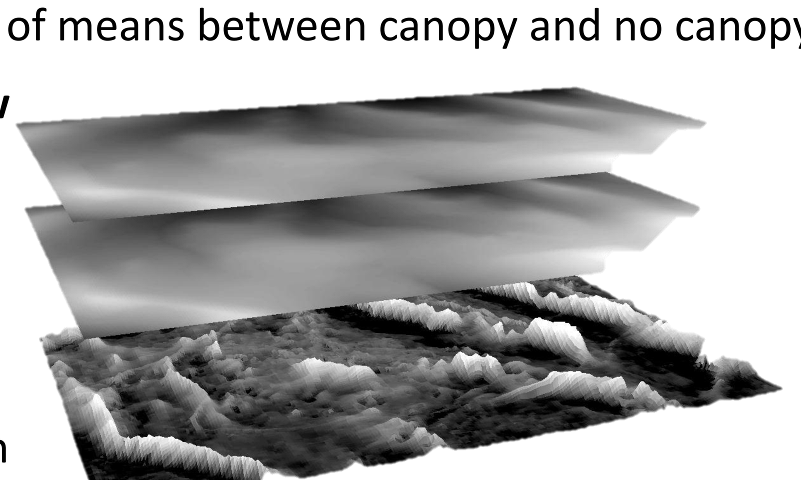
TLS sites on Grand Mesa

Site K. Snow on and snow off images from Site K

Approach:

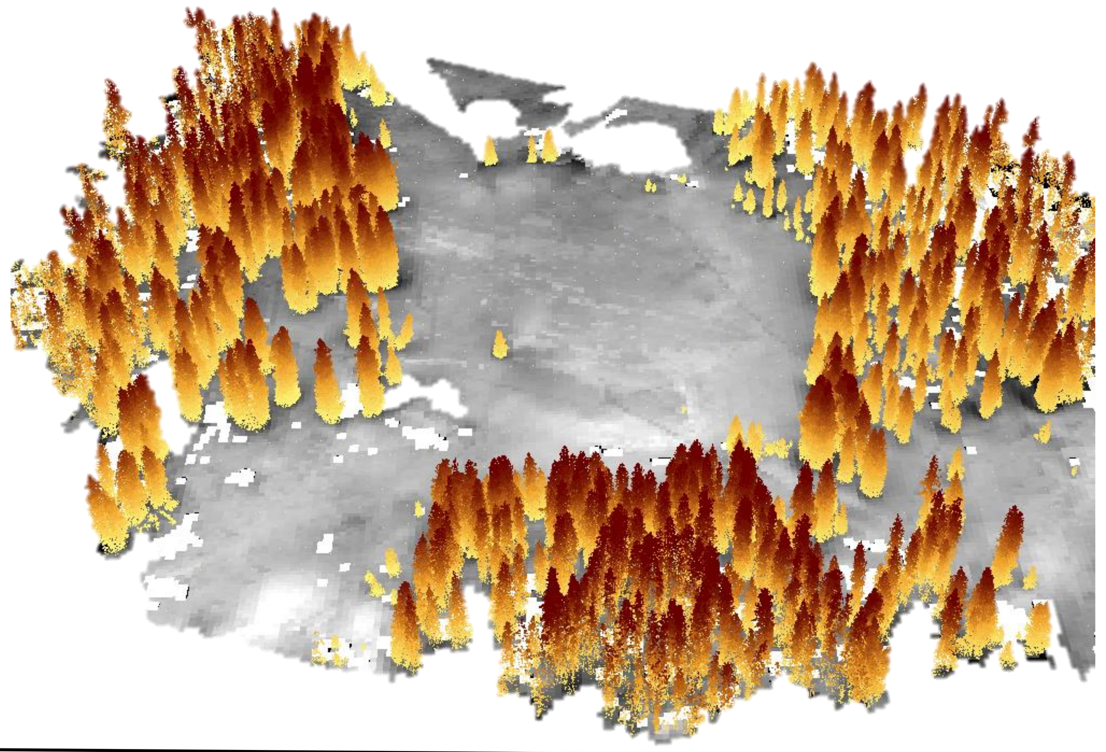
1. Classify point cloud into **ground** and **canopy** points.
2. Create Digital Elevation Models (DEM) (rasters) from snow on and snow off point.
3. Create rasters of snow depth (DEM's of differencing): snow on – snow off
4. Create canopy metrics from canopy classified points.
5. Identify correlation between metrics and snow depth – i.e. are any metrics predictive of relative snow depths (max ht, range, std deviation, etc.).
6. Difference of means between canopy and no canopy.

Creating Snow Depth maps: snow off is subtracted from snow on to yield snow depth (bottom layer).



DEM's of differencing. In this example, snow depth ranges between: 0.8-2.5m (note values stretched to emphasize contrast).

Snow depth map. Overlain with classified canopy point cloud – Site K



Preliminary Results

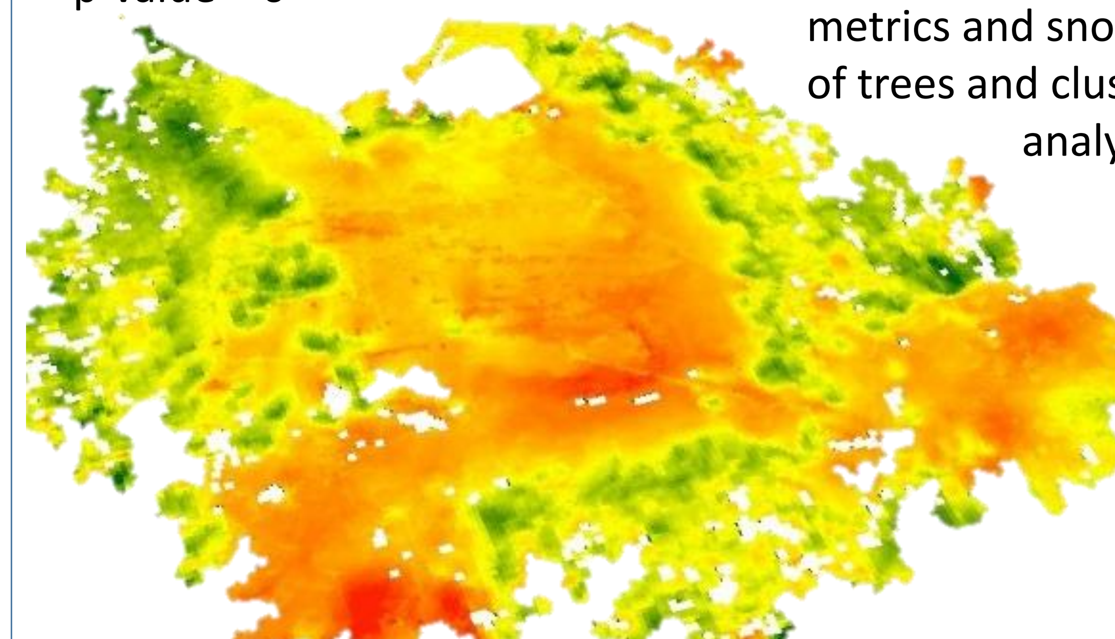
1. Comparison of means

- -Using canopy cover as a mask, select the area *outside of canopy*, and *under canopy*
- -*T-test* to compare means
- -*Two-sample t-test confirms statistically different means* of snow depth under canopy vs open.
- -p-value = 0

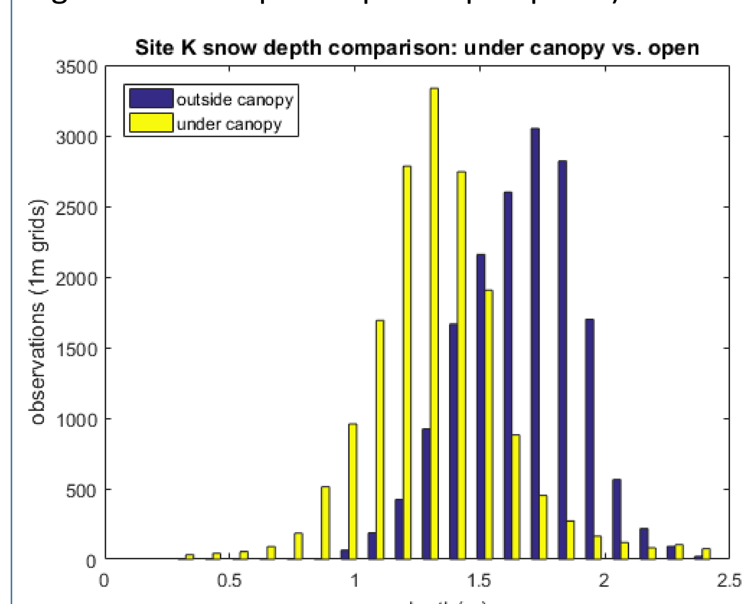
2. Correlation between snow depth and canopy

Computed a range of vertical canopy metrics such as foliar height diversity, standard deviation of height, mean height, and a suite of others to test for correlation to snow depth:

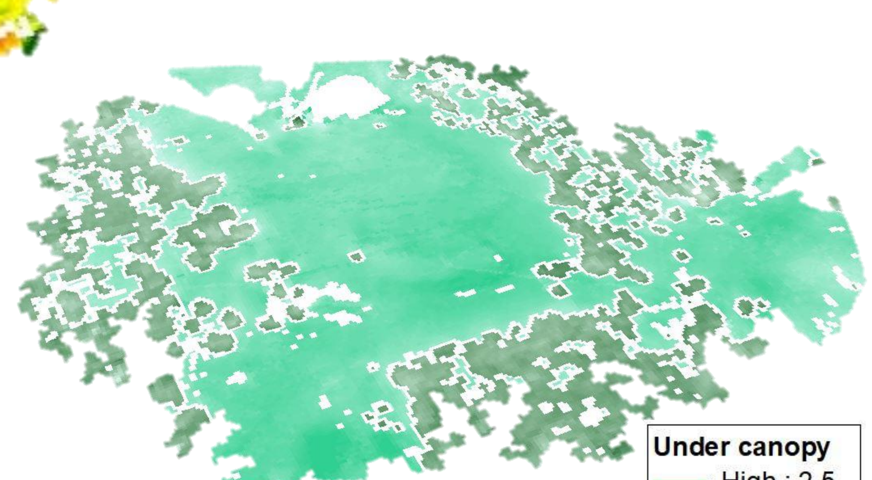
Conclusion*:* At the individual pixel scale, statistically weak correlation (Pearsons correlation coefficient) between canopy metrics and snow depths. Segmentation of trees and clusters should improve this analysis.



Site K snow depth map. Notice pockets of deeper snow (red) in SE corner of horseshoe-shaped forest cluster. *Note, this map same as figure 'Snow depth map' at top of panel).



Snow depth deeper in the open. Snow depth values under canopy vs. outside of canopy (from images on left). Histogram portrays values from ~16,000 1m^2 grid cells over entirety of Site K, derived from rasterized TLS point cloud.



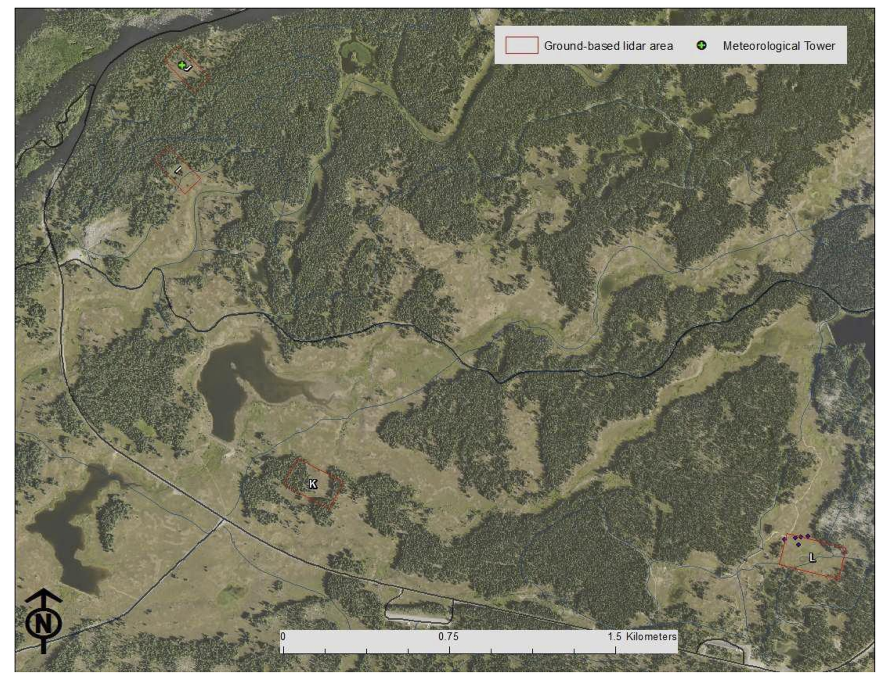
Snow map split – Under canopy and Outside canopy. Blue in the open, green under canopy.

Mean snow depth:
outside canopy: 168cm
Inside canopy: 132cm

Next Steps

Segment clusters

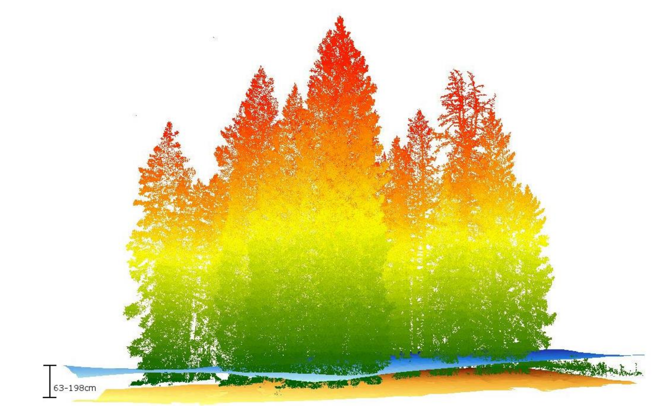
1. Individual tree and tree cluster segmentation.
2. Correlation using clusters and individual trees as objects to determine if properties such as surface area to volume, density or other bulk structural attributes of tree objects (clusters) are correlated to snow depth distribution.



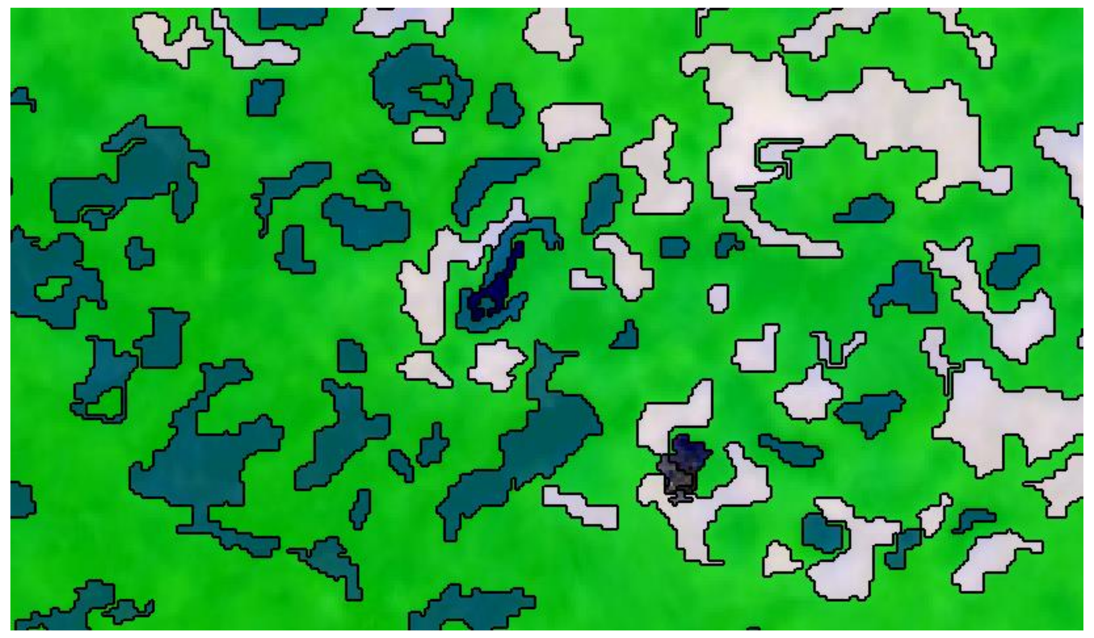
Aerial photo of are around Sites K and L. Forest cover and wind speeds span a gradient of increasing and decreasing values respectively from west to east along Grand Mesa.

More sites and temporal change

3. Measure change at sites scanned multiple time during winter
4. More sites!



Cluster from Site K. Ground in burnt orange, snow surface in blue. Small cluster Site K.



Sample of vegetation clusters. Light green represents open. Dark green and grey are different shrub species. (figure courtesy of Josh Enterkine).

Finally, evaluate patch characteristics and topography

1. Distance to forest edge
2. Orientation to forest edge – i.e. are snow drifts accumulating in preferential zenith perpendicular to cluster boundary?
3. Density of patch
4. Patch dynamics: size, density arrangement – Does patchiness of trees significantly alter the snow depth distribution.
5. Topo (slope, slope angle, surface roughness, etc.)

Citations

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Deems, J. S., S. R. Fassnacht, and K. J. Elder (2006), Fractal distribution of snow depth from LIDAR data, *J. Hydrometeor*., 7(2), 285 - 297.

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